Laboratory Testing of the Mini-Magnetospheric Plasma Propulsion (M2P2) Prototype

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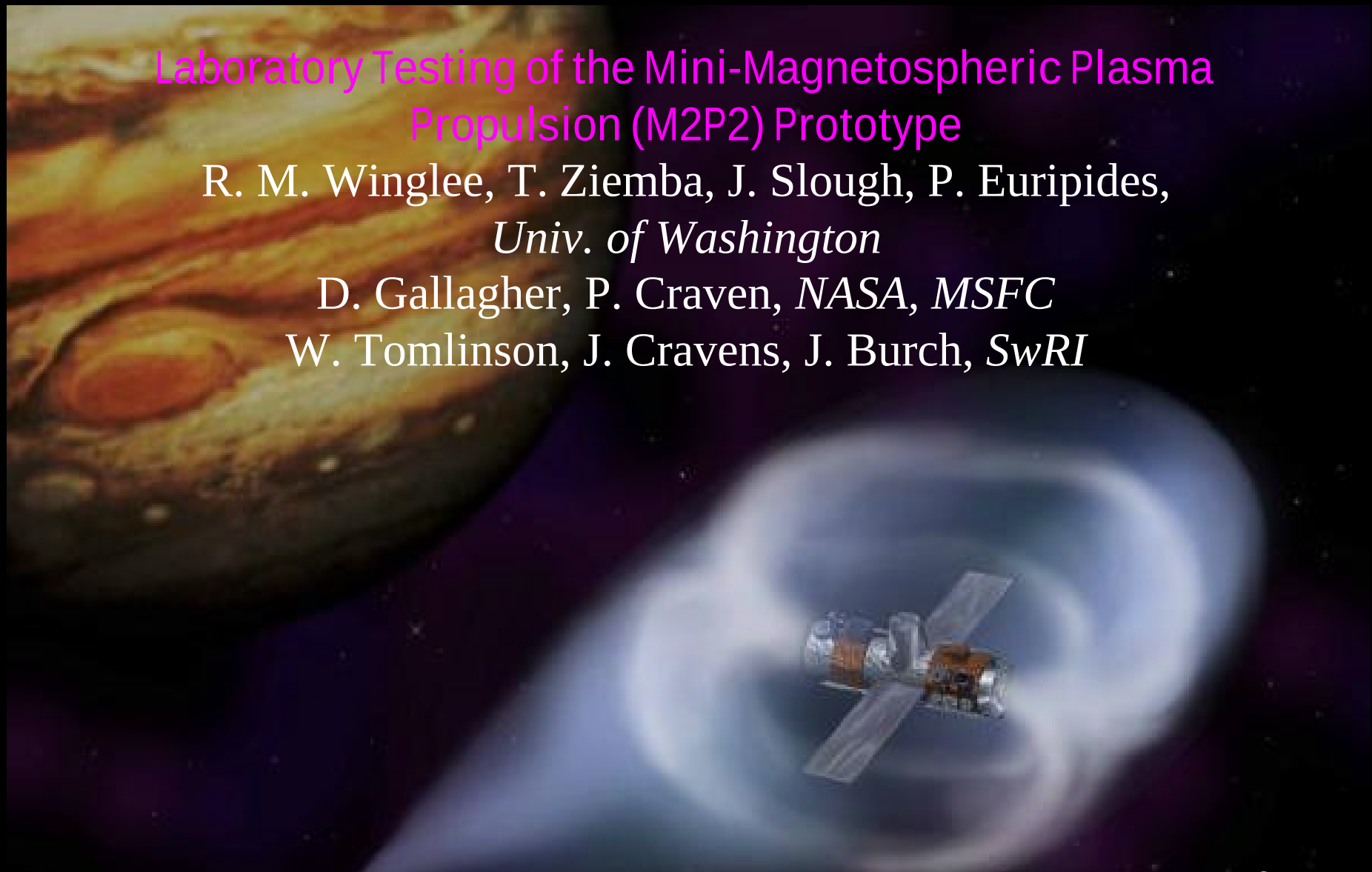
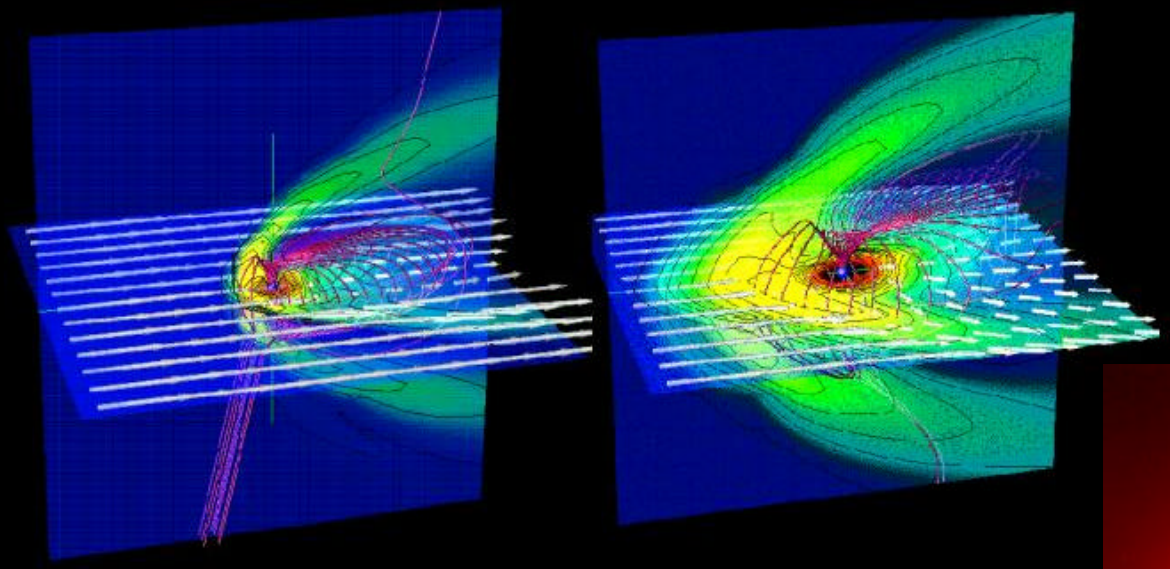


Create a magnetic bubble around and attached to a spacecraft that will be pushed by the solar wind to produce a substantial enhancement in the thrust on the spacecraft

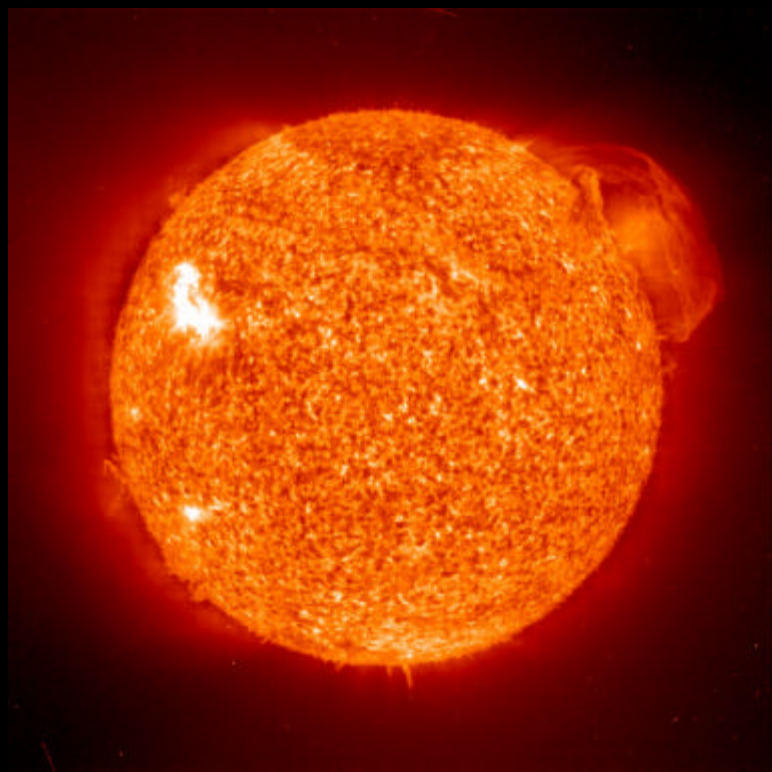
Magsail: Simple Dipole
→ $B \sim R^{-3}$
→ Limited Interaction Region

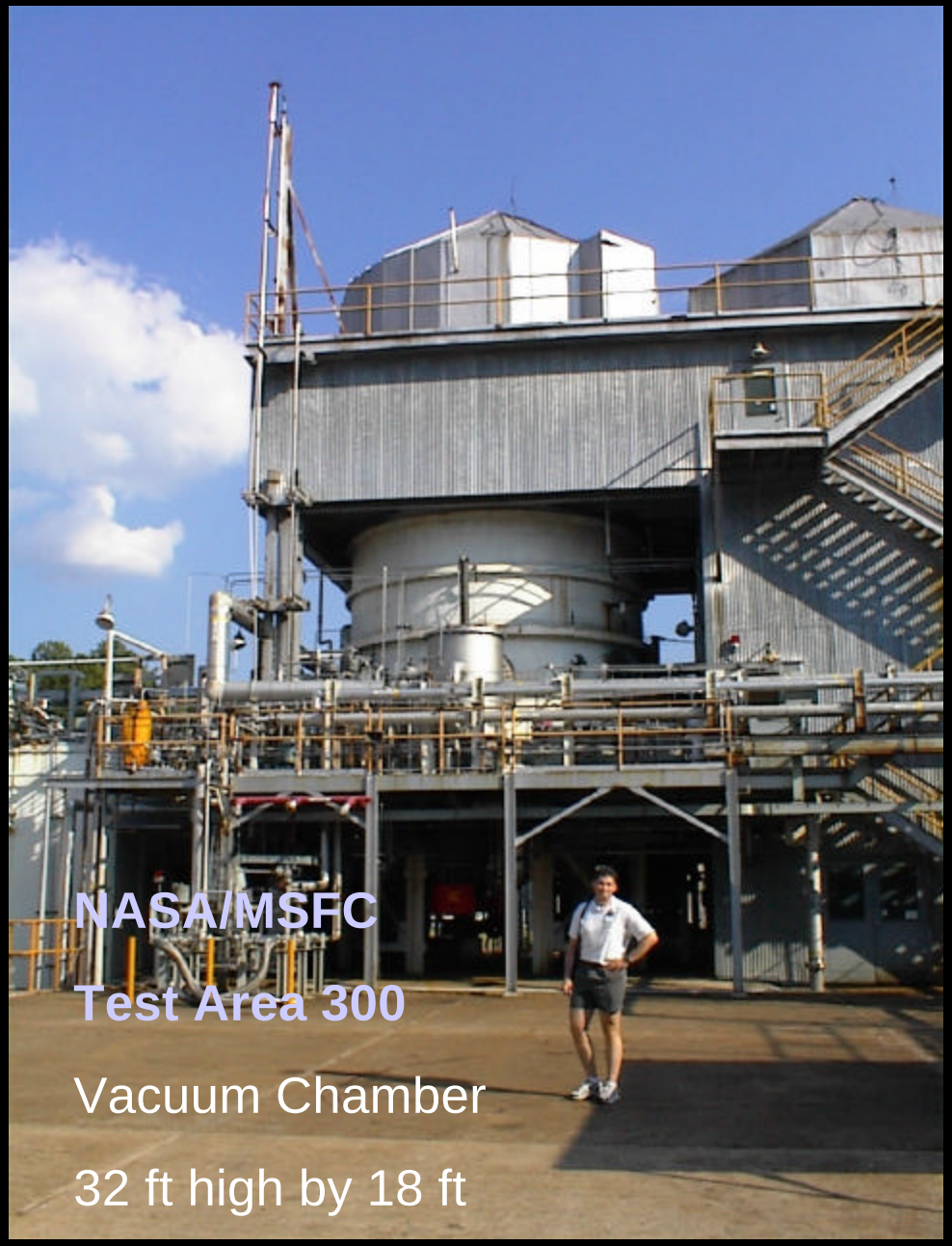
M2P2: Dipole+ Plasma
→ $B \sim R^{-1}$
→ Enhanced Interaction Region



Detailed Computer Simulations

Nature's Example: Eruptive Prominences

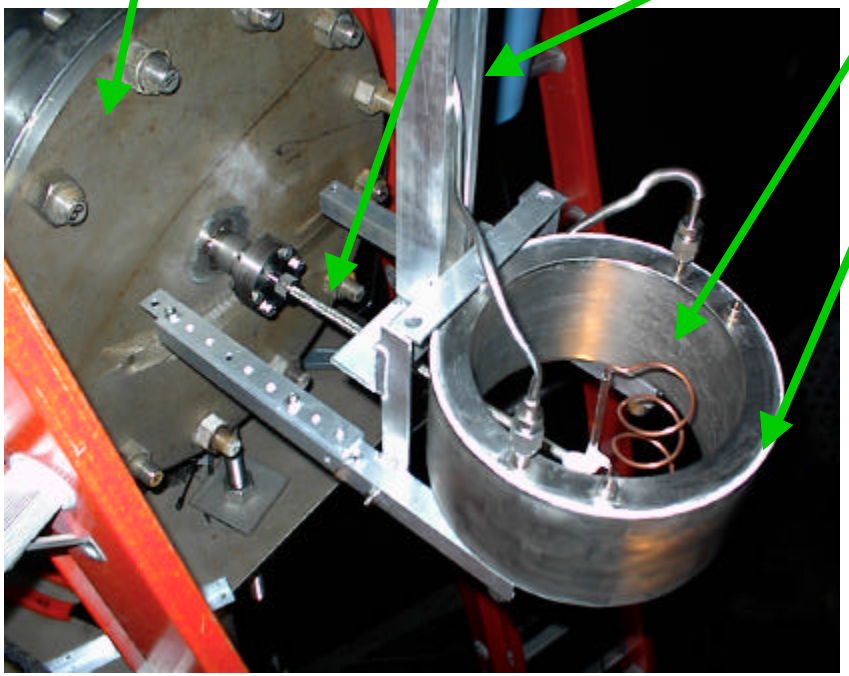




Objectives:

- Demonstrate Magnetospheric *Inflation*
- Demonstrate Magnetospheric Plasma *Deflection*

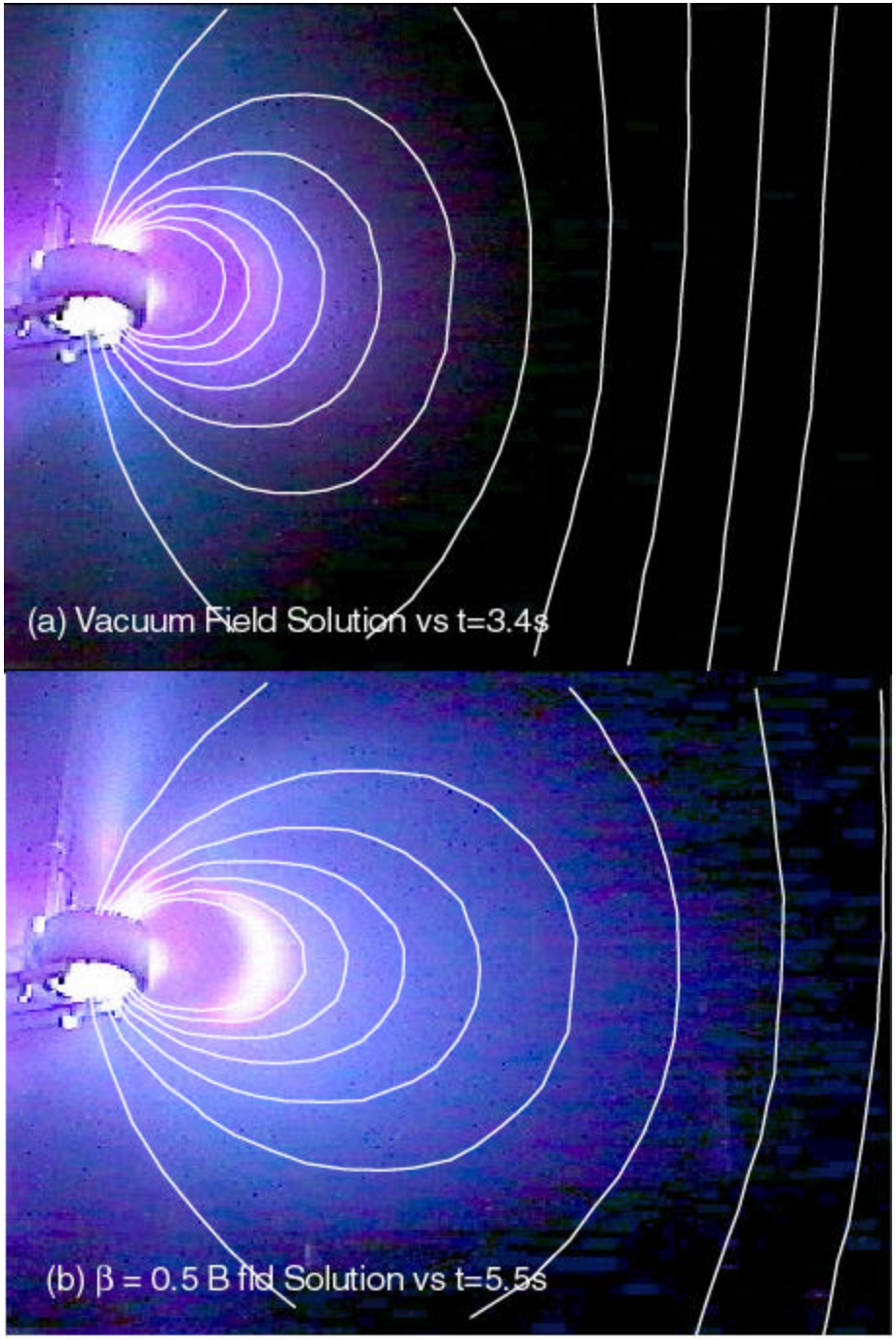
Mini-Magnetospheric Plasma Propulsion:
Prototype Development and Performance



- Variety of Propellants Possible
  - –Argon or Helium (for lab use)
  - –Liquid Hydrogen
  - –Water – refueling in space
  - –Other light weigh fuels : CH_4, NH_3 CO_2,

- Prototype Specifications
  - 11 cm radius magnet, 300-1000 G
  - Antenna, small (1.5 cm radius) and large (2.5 cm radius), ~ 1kW

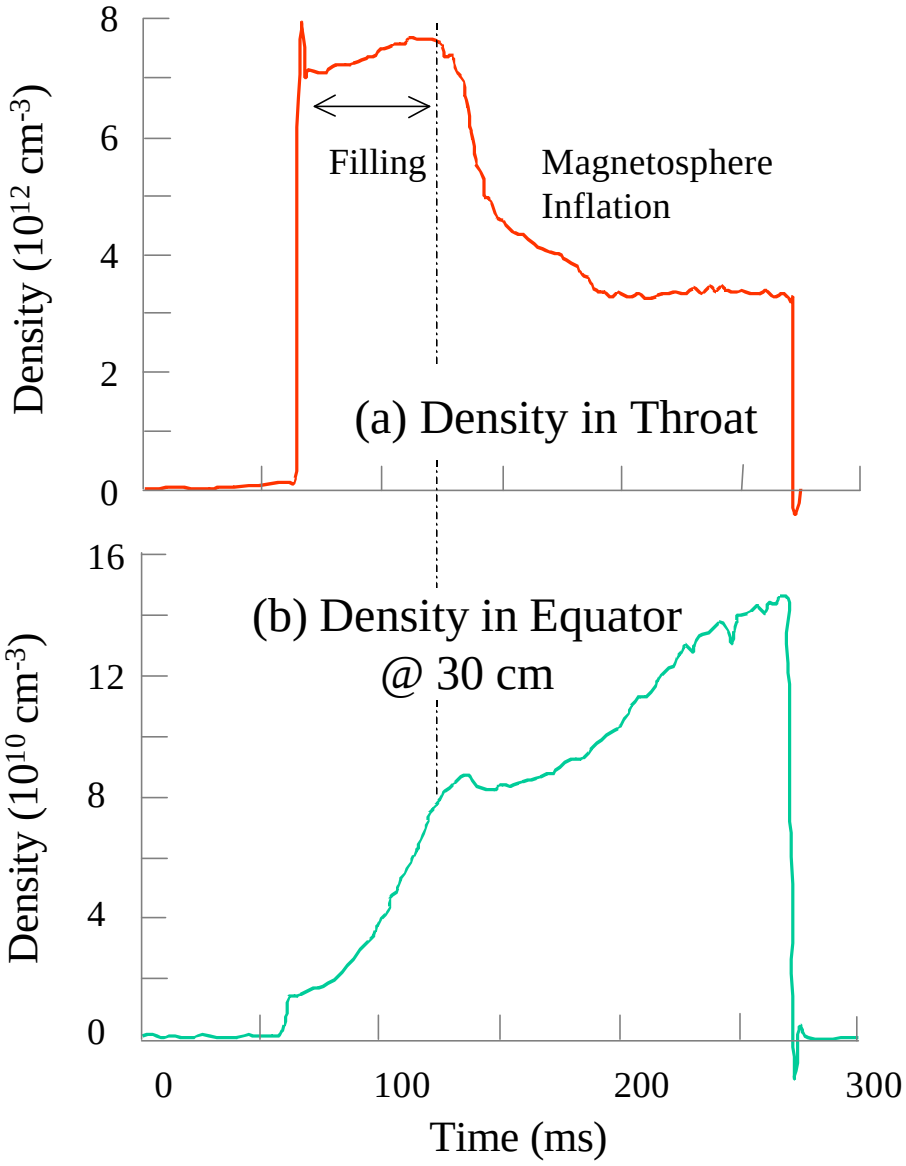
- Prototype Performance
  - Sustained densities of 10^{13} cm^{-3}
  - Temperatures of 4 – 12 eV
  - Small Antenna: 0.4 kg/day (5.4 mg/s) @ 25% gas efficiency, for 3.3 amps of plasma and 4 mN
  - Large Antenna: 0.8 kg/day (11 mg/s) @>50% gas efficiency, for 12 amps and 16 mN

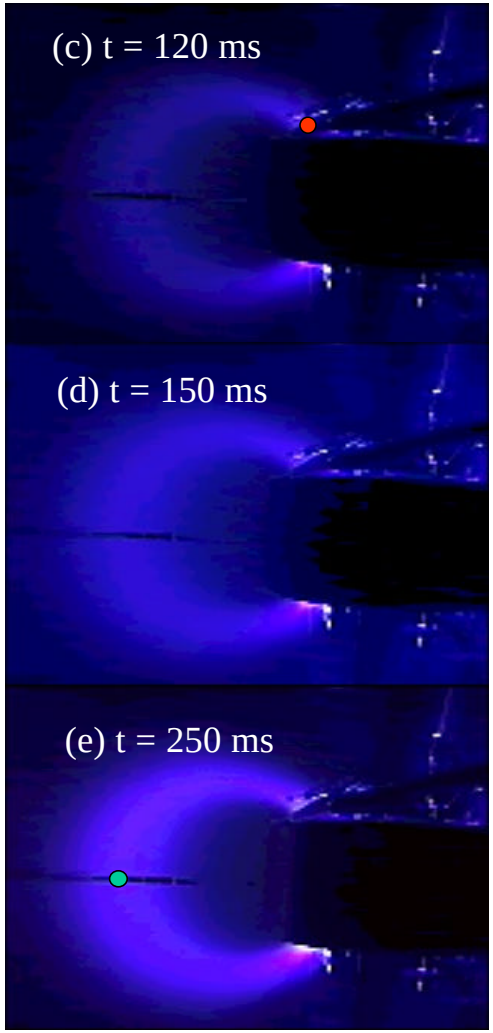


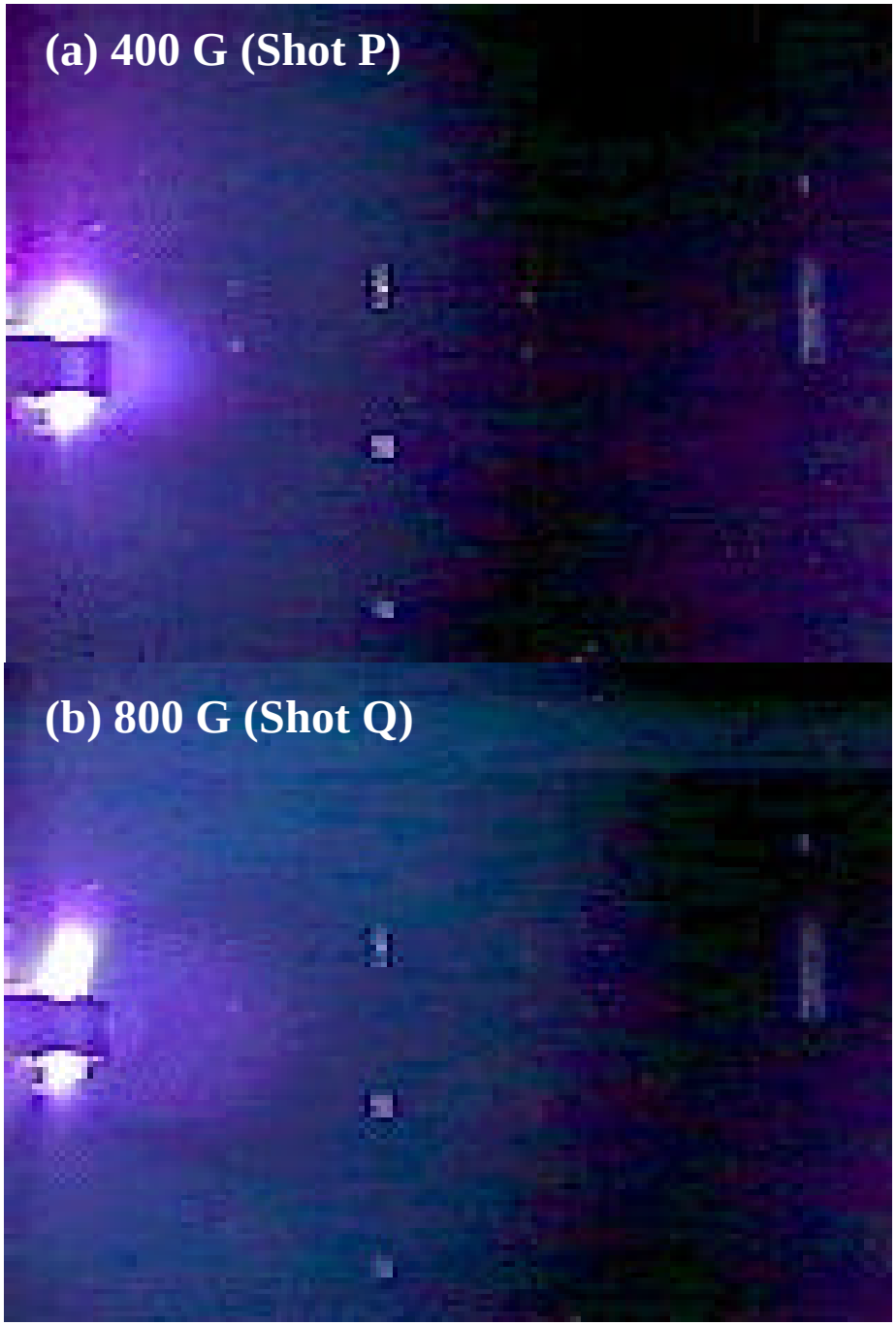
Demonstration of Plasma Expansion of a Mini-Magnetosphere:

- Large Chamber Tests at MSFC
  - Helium plasma @ 350 G
  - –Vacuum field solution shows no closed field lines within ~ 3ft
  - –Plasma emissions initially seen to closely match the vacuum field solution
  - –Expansion seen as plasma β approaches unity.
  - –Expansion out to at least **30 times** the magnet radius demonstrated.
  - –Main limitation due to recombination with chamber neutrals

Optimization of Performance to be Completed 2001







Demonstration of Plasma Deflection by a Mini-Magnetosphere: M2P2 vs SEPAC

- SEPAC (right hand side)
  - 4 Amp Xenon ion source
  - 800 W @ 1 eV
- M2P2 (left hand side)
  - ~ 4 Amps of Argon @ 400 W
  - the two sources separated by about 14 ft (only 6ft field of view around M2P2 shown in figures)
- Deflection
  - Permanent barrier (magnetopause) seen better the two plasmas
  - Barrier moves to the right as the magnetosphere is inflated
  - Barrier moves to right with increase magnetic field

Fundamentals of M2P2 Proven: Inflation and Deflection ➔

Fast Missions to Planets

A: 34 Day Acceleration Period arriving at Jupiter 470 days trip time

B: Break with the Jovian magnetosphere requiring an acceleration of 0.02 m/s/s

C: Accelerate back to Earth essentially along reverse course.

Mission Time : ~ 3 yrs.